Nb-Sn diffusional behavior

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Abstract

The diffusional behavior of electrodeposited tin on niobium thin tapes is evaluated. The experimental data have been elaborated with OtiginPro 8 to calculate the diffusion parameters, Q and D_0, that have been compared to other data found in literature. The diffusional parameters are important, because low diffusion values could prevent the excessive grain growth of the A15 phase, and enhance the superconductive properties of the material.

I. Introduction

A new approach to produce Nb_3Sn superconductors is the electrodeposition of a thin film of Sn on a Nb tape substrate, followed by an heat treatment, to generate the superconductive phase. The Nb substrate is highly cold-worked, so that the diffusion of tin is favored due to the great number of dislocations in which it can diffuse, following "preferential" paths. Electrodeposition guarantee a good adhesion of Sn to the substrate, so that the Nb sheet could be easily handled and curled, even in a wire shape. The experiments performed at the Fermilab Technical Division have been based on heat treatments performed at different times and Temperatures to define the diffusional parameters of the sample. The diffusional law that had been used is a simplified version of the second Fick's equation, and can be written as:

$$L = \sqrt{2Dt} \tag{1}$$

in which L represents the thickness of the Nb_3Sn phase formed at the interface between Sn and Nb, t is the duration time of the heat treatment performed at a constant temperature, and D is the interdiffusion coefficient between Sn and Nb and presents an Arrhenius Temperature dependent behavior:

$$D = D_0 e^{-\frac{Q}{RT}} \tag{2}$$

D_0 represents the diffusion frequency, R is the gas constant, and T is the temperature of the heat treatment.

II. Experimental Section

To perform the experiment the samples, with a dimension of 0.5x1.5 cm,were placed in a INOX sample older, and successively positioned in a tubular oven. To prevent oxygen and water contamination a vacuum pump was used to make vacuum, and successively pure argon was inflated in the oven. Different heat treatments at constant times, and later at constant Temperatures had been performed, as can be seen in **??**, necessary to determine the diffusion parameters.

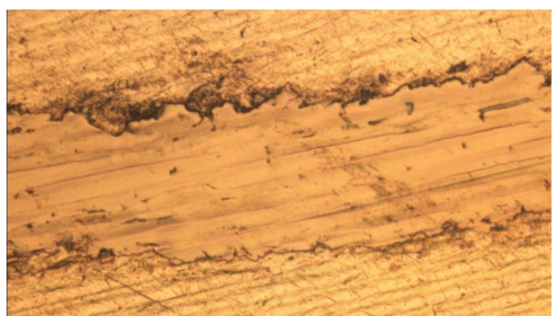

Figure 1: *Sample cross-section*

After the diffusion treatments the samples became fragile, and had to be handled with care. The obtained tapes were embedded in a cylindrical shaped epoxy-resin matrix, with the tape perpendicular to the bases, so that the cross section could be observed with an optical microscope. A subsequent multi-step polishing was required to obtain a smooth enough surface to be studied. The first step was sewing the sample, than scrubbing it with always lower granulometry sandy paper, and finally polishing it with a spinning machine on a soft pad wet by a silicon suspension on $1\mu m$. To determine the phase thickness L and the error on the measurments, ten datapoints had been measured for each sample.

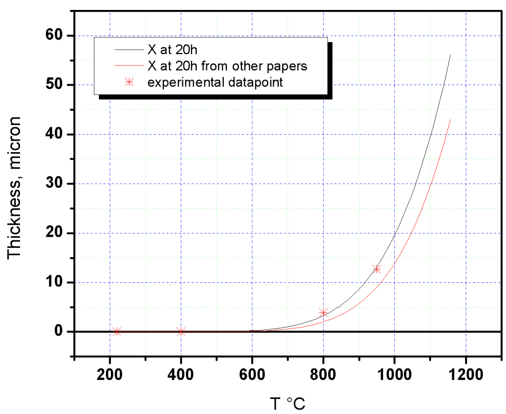

Figure 2: *Constant time curves*

III. Experimental Results

An average value of L and the standard deviation was calculated for each sample, and all the obtained values were plotted in OriginPro8 to fit a curve, as can be seen in 2, and extrapolate the diffusion parameters Q and D_0 of 2.

-	Paper	Experimental
Q	$218KJ$	$202KJ$
D_0	$4.4 * 10^9$	$2.3 * 10^9 \mu m$

The value of Q obtained is smaller than the one found in literature, and it means that in the electrodeposited samples, the activation energy for diffusion is lower. The lowering of this energetic barrier favors the diffusion D of the metals, so that, at the same time and Temperature a thicker superconductive phase layer L is formed. This is probably due to the big amount of dislocations found in the cold-worked niobium substrate, that are defects in the crystal lattice, which favor the diffusion of Sn atoms in the Nb lattice, and fasten the process.

This allows to perform quicker heat treatments, or treatments at lower temperature. Low reaction time and Temperature is desired to obtain a small grain growth, since the average grain diameter grows with the Temperature power of three. Small grains are required to obtain a good superconductive behavior, since grain boundaries, that are non superconductive, act as flux pinning centers, and block the fluxons, hindering the degradation of the superconductive properties. Small grains means a lot of surface area available to flux pinning.

sample	1	2	3	4	5
time [h]	100	40	40	20	20
Temperature [°C]	200	400	800	800	950
Phase thickness [μm]	-	-	4.2	3.9	12.7
Standard Deviation	-	-	0.36	0.44	0.48